# Pioneer 11 Saturn Encounter Support

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*This article reports on activities of DSN Operations in support of Saturn Encounter Operations of Pioneer 11.*

## I. Introduction

This article is mainly concerned with the preparation of the Deep Space Network for support of Pioneer 11 Saturn Encounter Operations. Points that will be discussed include: the encounter's main objectives, DSN testing, special DSN configurations and procedures, Radio Science activities, and any other mission-related activities.

## II. Mission Operations and Status

The Pioneer 11 spacecraft was launched on April 6, 1973 and began its long cruise to Jupiter, which it encountered on December 3, 1974. By using Jupiter's strong gravitational field, the Pioneer 11 spacecraft's trajectory was redirected for its flight to Saturn, which it will encounter on September 1, 1979. The total cruise time between Jupiter and Saturn will total 1732 days. Throughout this cruise phase, the spacecraft has remained in excellent condition with very few system malfunctions. During this cruise period, the DSN has routinely tracked Pioneer 11 under the direction of Pioneer 11 operations at the Ames Research Center (ARC) located at Moffett Field, California.

## III. Encounter Description and Objectives

As stated above, Pioneer 11's closest approach to Saturn will occur on September 1, 1979. Earth-received time for periapsis will be about 1756 universal time coordinated (UTC), with a round-trip light time of 2 hours and 52 minutes. The actual encounter period began on August 2, 1979 (encounter minus 30 days), and will end on October 1, 1979 (encounter plus 30 days). The spacecraft will pass within 81,426 km (1.36 Rs) of Saturn at periapsis. Inclination of the trajectory will be 6.5 degrees to the Saturn equator, with periapsis occurring in the southern hemisphere. Earth and solar occultations occur shortly after periapsis.

Besides the observation of Saturn itself, the other major objectives of this encounter will be to get a better observation and understanding of its rings and a close observation of Saturn's largest moon Titan. The spacecraft will pass within an estimated 3400 km under the edge of the visible rings, and its closest approach to Titan will be approximately 356,000 km.

During this encounter sequence, an estimated 25,000 real-time commands will be required, most of which are required to operate the Imaging Photo Polarimeter (IPP). The IPP imagery will exceed Earth-based resolution at encounter minus 6 days. Figure 1 shows the Saturn flyby trajectory as viewed from Earth, and Figure 2 shows the heliocentric geometry of the Pioneer 10 and 11 trajectories and positions on September 1, 1979. Table 1 also lists the closest approach events at Saturn and its satellites. The Project is expecting 50 pictures of better-than-Earth-based quality during encounter. Twenty will be taken prior to periapsis and thirty following encounter. For a further description of the Saturn encounter, see Ref. 1.

Saturn-Earth occultation will occur shortly after encounter and last for about 78 minutes. Data taking for this event and the Occultation Experiment will begin one hour prior to entry and continue until one hour following exit. The entry phase will be supported by both DSS 63 and DSS 14. The exit will be supported by DSS 14 only, since DSS 63 will have set by that time. The spacecraft will be in the two-way mode at entry with DSS 62 providing the uplink. Upon exit, DSS 12 will be two-way noncoherent with the spacecraft and providing the uplink. The uplink sweep will be timed to start a one-way light trip time prior to spacecraft exit.

Superior Conjunction occurs on September 11, 1979. The Sun-Earth-Probe (SEP) angle at encounter will be 8 degrees. This angle will decrease to 1.75 degrees on September 11. The data rate will be decreased as the SEP angles decrease below 3 degrees. The period of angles less than 3 degrees is expected to be September 8 through September 14. Solar flare activity could alter these data degradation dates. Figure 3 shows the Sun-Earth-Saturn angle, which is nearly equal to SEP, in degrees versus the date.

Like Pioneer 10, Pioneer 11 will escape the solar system on its postencounter trajectory. Pioneer 11 will travel in the opposite direction of its sister ship. The escape asymptote is in the general direction of the solar apex, which is in the opposite direction from the Sun's motion through the interstellar medium. The spacecraft may be tracked through 1987.

## IV. Special DSN Configurations and Procedures Required for Encounter Support

The 64-meter subnet, consisting of DSS 14 (California), DSS 43 (Australia), and DSS 63 (Spain), will be supporting the encounter phase. During the period of encounter ± 7 days, the 26/34 meter subnet will provide dual-station coverage. During this period, the 64-meter stations will be in a listen-only mode, and the 26/34-meter stations will provide the uplink for commanding the spacecraft. An improvement of 0.8 dB in the downlink is expected in the listen-only mode. Figure 4 shows the 64-meter ground station configuration, and Fig. 5 shows the 26/34-meter configuration.

The configuration for support of occultation by DSS 14 and DSS 63, as described in paragraph III of this article, is shown in Fig. 6.

### A. Antenna Arraying

During the encounter ± 7-day period, a Research and Development antenna array technique will be used at Goldstone to gain additional telecommunications performance on a best efforts basis. Arraying is expected to provide an expected SNR improvement above elevations of 15 degrees of 0.4 to 0.5 dB. The signals from DSS 12 and DSS 14 are combined using a Real-Time Combiner (RTC) at DSS 14. This configuration is shown in Fig. 7 at a gross level and in more detail in Fig. 8.

### B. Contingency Manual Commanding

In the event of a failure in the ARC Command System or communications between Ames and the DSN that would prevent the transmission of commands in the automatic mode, the Project may require certain safing commands to be transmitted in the manual mode.

Due to the complexity and length of these safing command sequences, a special command procedure has been developed. For proper spacecraft response to the command sequence, the commands must be transmitted contiguously.

### C. Exciter and Receiver Ramping

The closest approach will be less than two Saturn radii from the center of the planet and the doppler rates are expected to be extremely high, nearly 80 Hz per second (S-band), prior to entering occultation. This coupled with low signal levels will present a less than optimum tracking situation for ground receivers. In addition, the spacecraft receiver will see more frequency change than it can track.

To help alleviate the problem, the use of exciter and receiver linear ramps using Programmed Oscillator Control Assemblies (POCAs) at both prime encounter complexes will be utilized. Therefore exciter POCAs have been installed at DSS 62, and exciter plus receiver POCAs installed at DSS 12. The prime 64-meter stations (DSS 14 and DSS 63) already had POCAs.

A ramping strategy is being developed and will be used during the encounter tests described later in this article.

## V. DSN and Project Preencounter Test and Training

To perform at an optimum level during Saturn encounter, the DSN and the Pioneer Project have pursued an extensive training program prior to encounter to perfect the use and understanding of the procedures and configurations described above. Each phase of this program is discussed below, including all available results.

### A. Contingency Manual Commanding Operation Verification Tests (OVTs)

A total of 48 OVTs were conducted with the Deep Space Stations, which began July 2, 1979. The stations tested were the 26/34-meter subnet consisting of DSS 12 (California), DSS 44 (Australia), DSS 62 (Spain) and the 64-meter subnet made up of DSS 14 (California), DSS 43 (Australia), DSS 63 (Spain). Each operational crew was tested twice amounting to eight OVTs per facility. The Pioneer Project at ARC also used these tests to train their operators in the use of the new command procedures. The overall results of this testing effort was very successful and all personnel participating gained an excellent understanding of the procedures and their utilization.

### B. Saturn Encounter OVTs

Prior to encounter, the DSN will conduct OVTs simulating actual events that will occur during the encounter period. There will be one OVT conducted with DSS 12, DSS 14, DSS 62, and DSS 63.

The objective of each OVT may vary somewhat, as follows: the DSS 12 test will demonstrate receiver ramping and post occultation uplink reacquisition; at DSS 62, the test will demonstrate uplink exciter ramping capability; the tests at DSS 14 and DSS 63 will demonstrate the operations to be performed at each station during their encounter passes. These will include the use of receiver ramps, utilization of the Occultation Data Assembly (ODA) and the Digital Recording Assembly (DRA), the use of the Pre-Post Recording (PPR) system, and the processing of 1024 bits/s coded data.

At this writing successful encounter tests have been conducted at DSS 62 on August 15, 1979, and at DSS 63 on August 16, 1979. The results from tests at DSS 12 and DSS 14 are not available at this time.

### C. Antenna-Array Testing at DSS 12 and DSS 14

To accurately determine whether or not the antenna-array technique will prove advantageous during encounter, testing will be conducted using live Pioneer 11 1024 bits/s coded data. Therefore, testing will be accomplished by utilizing demonstration tracks over DSS 12 and DSS 14 prior to encounter. The stations will utilize the configurations depicted in Figs. 5 and 6 during these training passes. The main objectives of these passes will be to verify precalibration procedures, measure the performance of the RTC, validate RTC operational procedures, measure DSS 12's and 14's operational readiness, verify the performance of the DSS 12/14 microwave communications link, and verify the overall antenna-array configuration.

As in the case of some encounter OVTs mentioned above, these tests have yet to be completed at this writing, so no results are available.

## VI. Pioneer 11 Radio Science Activities

During the encounter period, three radio science experiments will be supported by the DSN.

### A. Ring Plane Crossing and Occultation

On September 1, 1979 (encounter day), DSS 14 and DSS 63 will support an experiment involving the ring plane crossing and occultation. The ODA will be used to take data during this exercise, with the DRA being used for backup data collection. Due to encounter uncertainties, a wide open-loop receiver bandwidth of 8 kHz will be used.

### B. Solar Corona Experiment

Beginning on September 2, 1979, ODA data will be taken continuously until September 24, 1979, in support of the Solar Corona Experiment. The narrow open-loop receiver 100-Hz bandwidth will be used for this support with a quantization of 8 bits.

### C. High Latitude Solar Wind Experiment

This experiment, known as the Grand Parade, will begin on September 6, 1979. The 64-meter subnet will again utilize the ODA in support of this experiment. The open-loop receiver bandwidth will be 100 Hz and the quantization will be 12 bits.

## VII. Summary

In this article we have discussed the Pioneer 11 mission, the Saturn encounter plan, a preencounter preparation plan, and the special activities that will be associated with the encounter. Because of the effort taken prior to Pioneer 11's arrival at Saturn, all participants are highly confident of a successful outcome.

# Reference

1. Miller, R. B., "Pioneer 11 Saturn Encounter Mission Support," in *The Deep Space Network Progress Report 42-52*. Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1979, pp. 4–7.

**Table 1. Pioneer 11 closest approach events at Saturn and Saturn satellites**

| Satellite | Closest approach, km | Encounter time, hours: minutes | Ground received, DOY/UTC |
|---|---|---|---|
| Phoebe | 9,453,000 | - 128:32 | 239/0928 |
| Iapetus | 1,039,000 | - 82:29 | 241/0731 |
| Hyperion | 674,000 | - 28:03 | 243/1357 |
| Dione | 291,100 | - 00:30 | 244/1730 |
| Mimas | 103,400 | - 00:07 | 244/1753 |
| Saturn | 81,426 | 00:00 | 244/1800 |
| Tethys | 331,700 | + 01:54 | 244/1954 |
| Enceladus | 225,200 | + 01:59 | 244/1959 |
| Rhea | 341,900 | + 06:00 | 245/0000 |
| Titan | 356,000 | + 25:31 | 245/1931 |

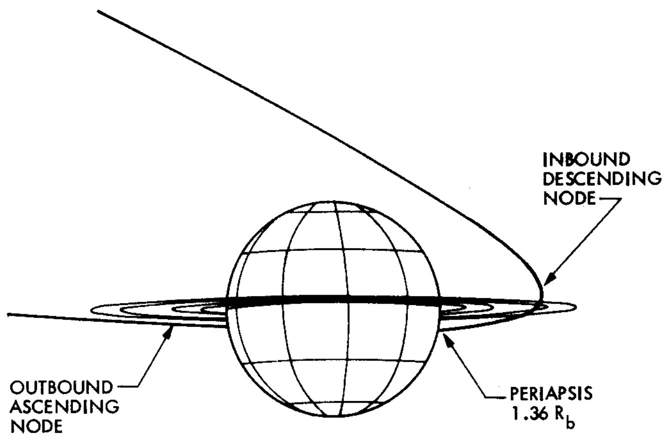



**Fig. 1. Earth view of Pioneer 11 Saturn flyby – balanced ring plane crossings at 2.87 $R_s$**

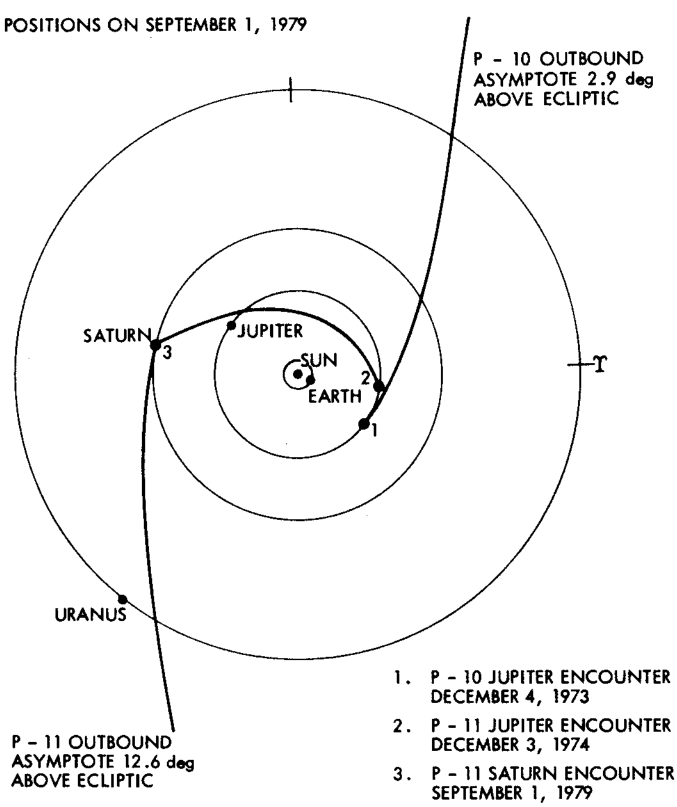



**Fig. 2. Heliocentric geometry of Pioneer 10 and 11 trajectories**

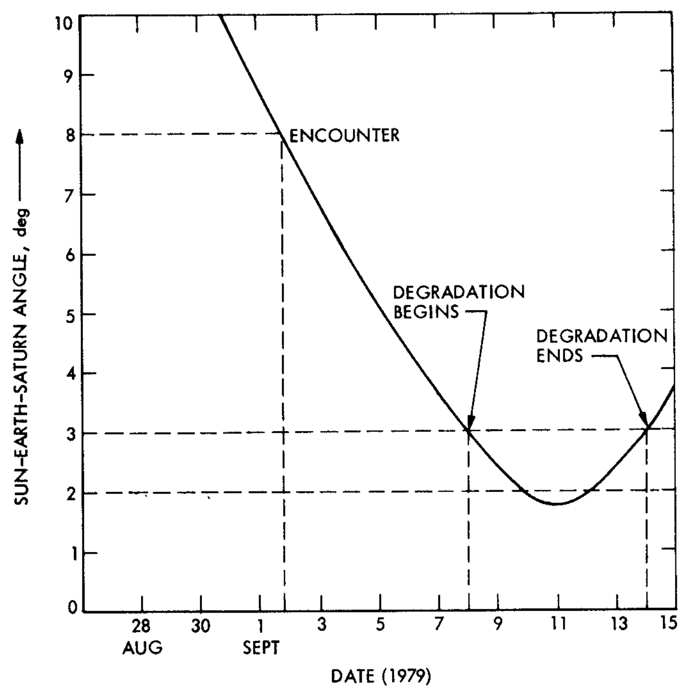



**Fig. 3. Angular separation of Sun from Saturn for Pioneer 11 encounter at Saturn**

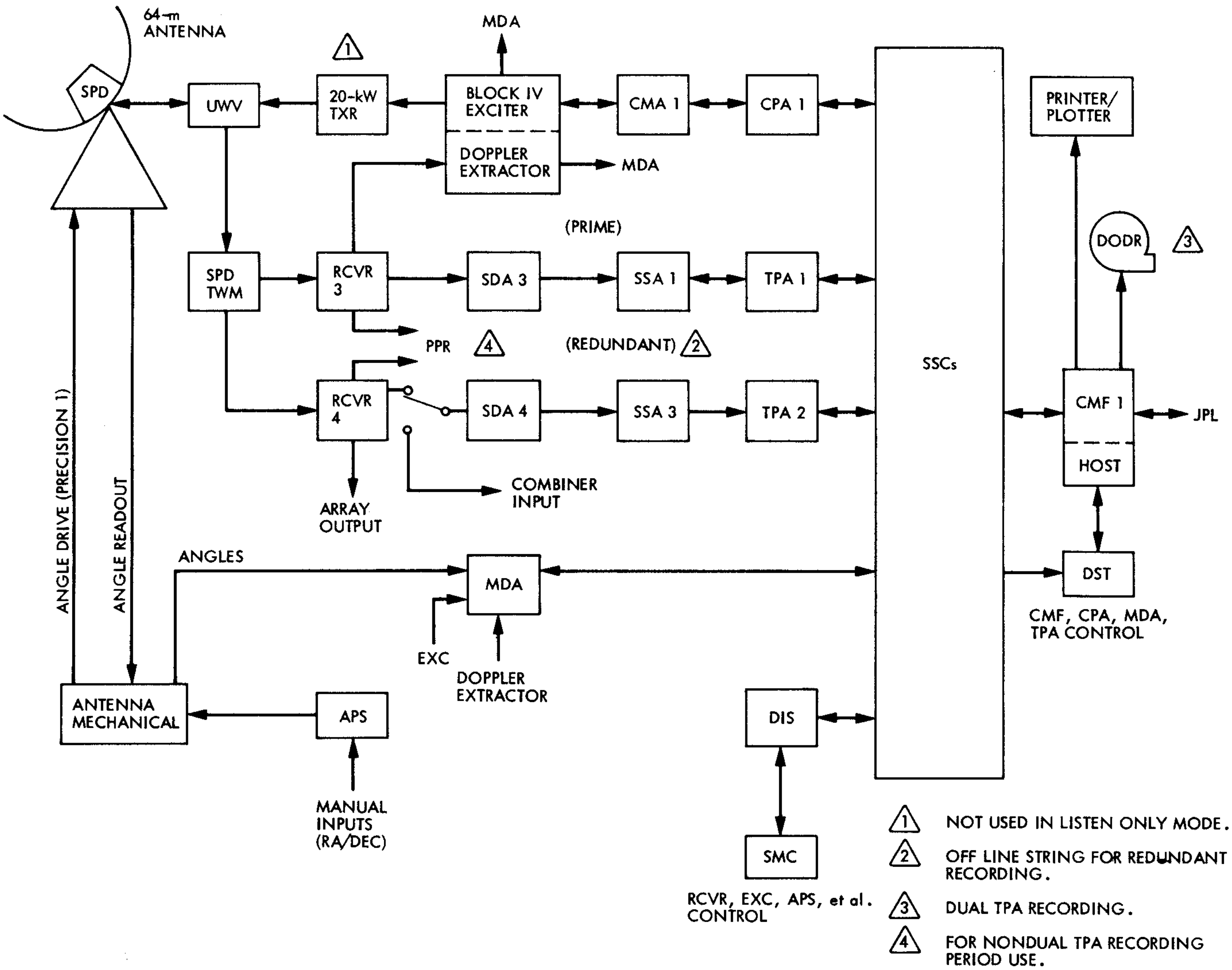
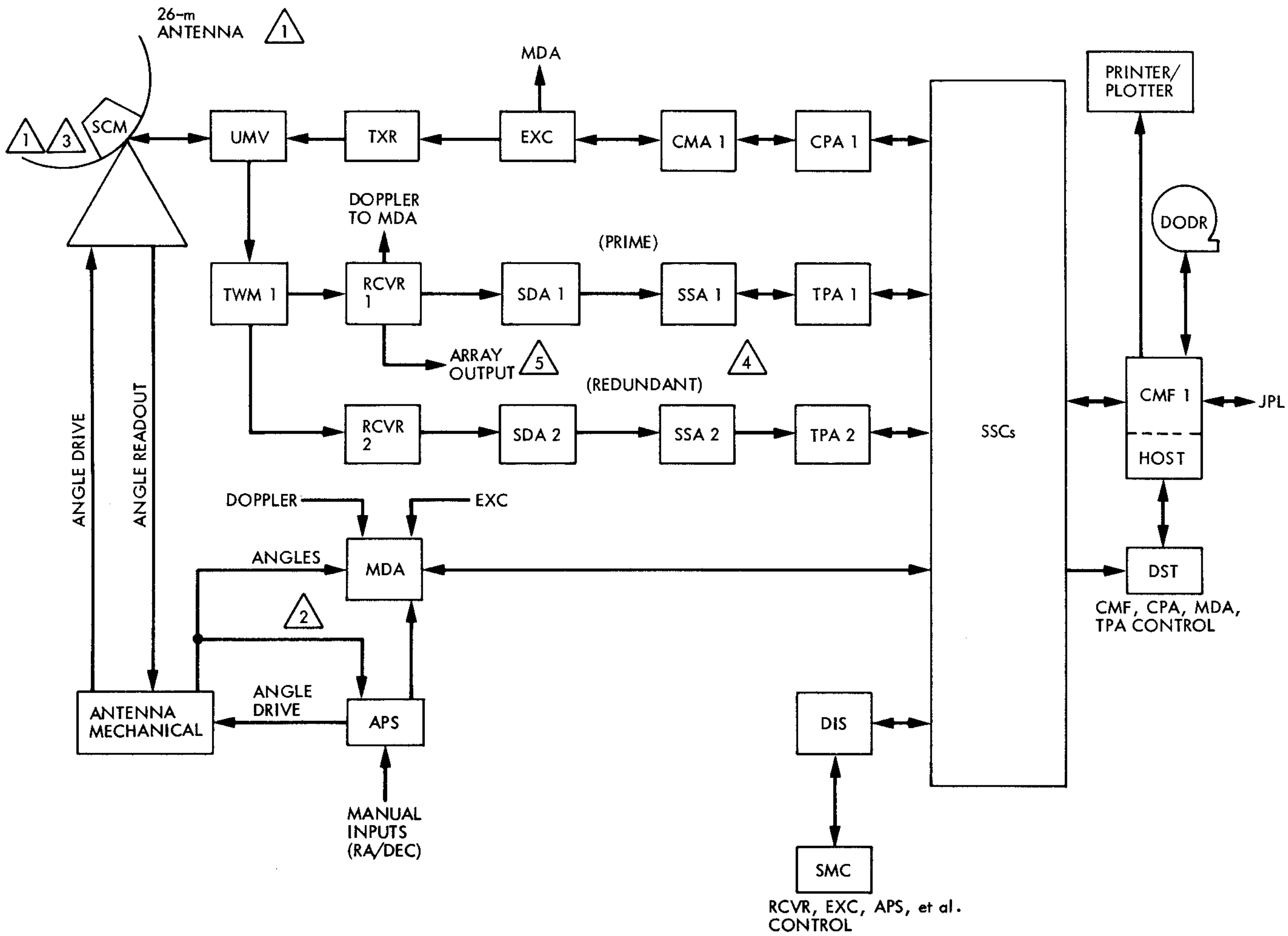



**Fig. 4. 64-meter Pioneer encounter configuration**




1 34-m AT DSS 12.

2 DSS 44 ONLY. BINARY ANGLE READOUTS CONVERTED TO BCD IN APS, THEN ROUTED TO MDA.

3 SXD AT DSS 12.

4 FOR USE IN CASE OF PRIME STRING FAILURE.

5 DSS 12 ONLY.

6 PRIME TLM STRING WILL BE DETERMINED BY RCVR CONTAINING 3 Hz LOOP FILTER.

**Fig. 5. 26/34-meter Pioneer encounter configuration – DSSs 11, 12, 44, and 62**

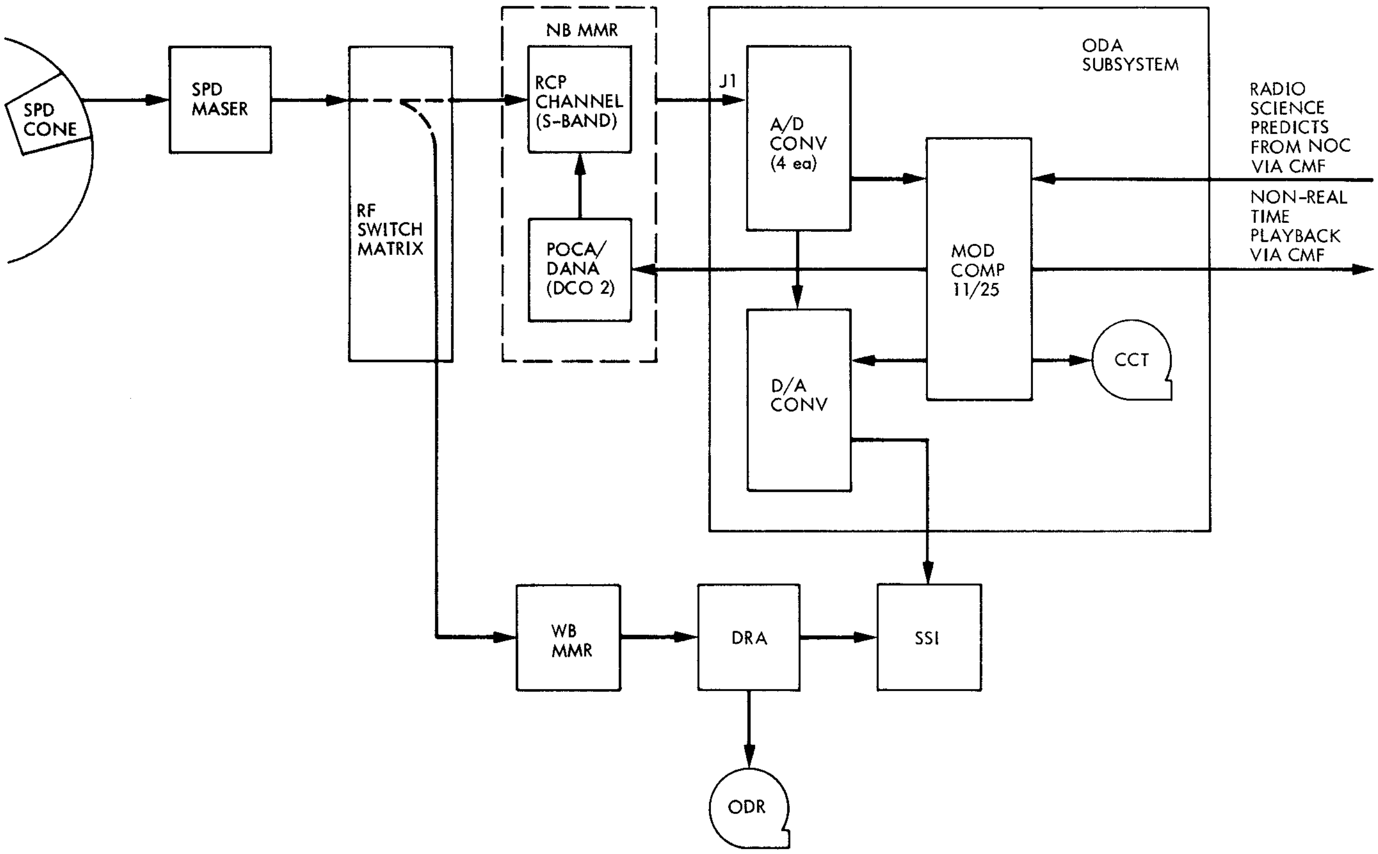



**Fig. 6. Occultation experiments (S-band) configuration**

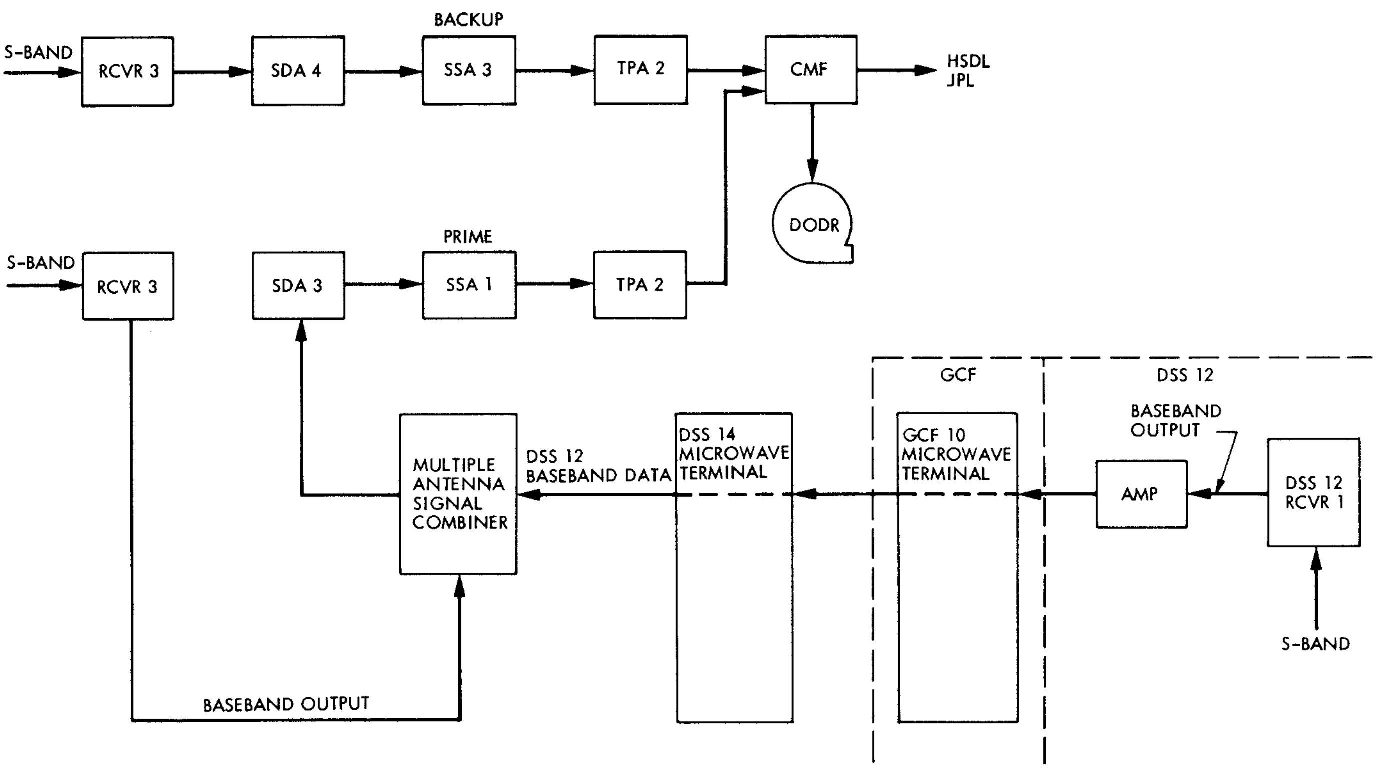



**Fig. 7. DSSs 12/14 antenna array configuration**

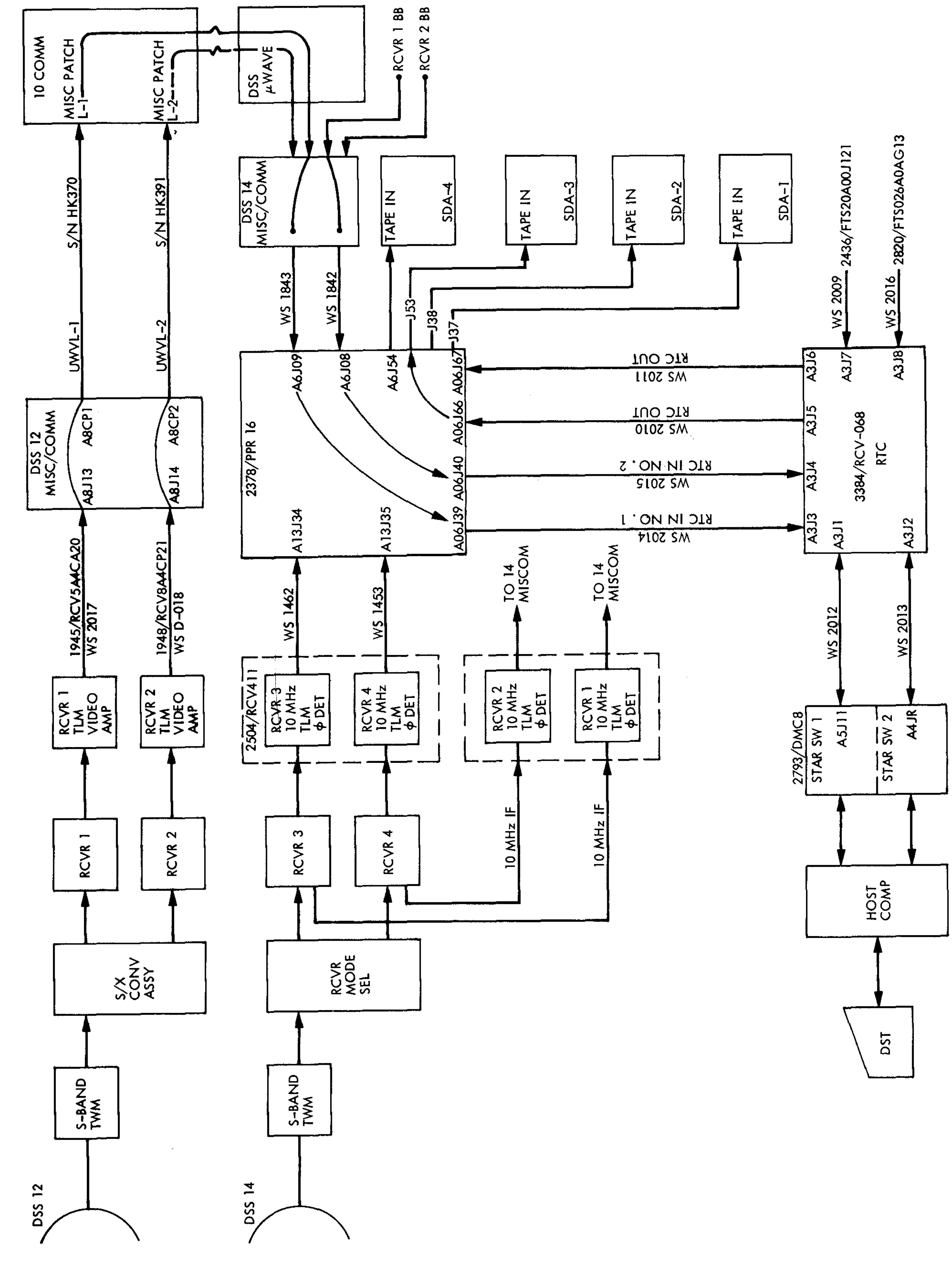



**Fig. 8. Real-time combiner interface/configuration**